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DASCAR SENSOR SUITE AND VIDEO DATA SYSTEM*

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ABSTRACT

A research program oriented toward the development of a portable data acquisition system for crash avoidance research has been conducted. This paper discusses the background to the project and the requirements for the data acquisition system. It also provides a brief system overview and describes two of the system's five major elements, the sensor suite and the video data system, in detail. Components, functions, and specifications are covered. Finally the paper addresses the central data collection/analysis facility which was assembled to manage the sensor and video data, and presents the potential uses of the data acquisition system

Keywords: data acquisition system, crash avoidance research, sensor suite, video data system

1. INTRODUCTION

Oak Ridge National Laboratory (ORNL) recently completed a two-phase, multi-year research program for the United States (U.S.) Department of Transportation, National Highway Traffic Safety Administration (NHTSA). The primary objective of the project was to develop a portable data acquisition system for crash avoidance research (DASCAR) that will allow driver performance data to be collected using a large variety of vehicle types and that will be capable of being installed on a given vehicle type within a relatively short time frame.

During phase I a feasibility study for developing DASCAR was conducted. Parameters and measures that could be collected; analysis tools and methods that could be used to assemble, analyze, and evaluate the gathered data; and measurement techniques and state-of-the-art hardware to support development of an in-vehicle data acquisition system were identified. Design requirements and specifications for DASCAR were also prepared and the cost of one or more copies of the data acquisition system was derived. Phase I research is covered in a paper by Carter, Spelt, and Barickman (1996).

In phase II of the research DASCAR was actually developed and validated. A development plan was designed and the driver performance data acquisition system was constructed. An evaluation plan was subsequently prepared and the validation was conducted. The system was then updated and pilot research was performed.

2. BACKGROUND

Given the diverse nature of circumstances leading to motor vehicle crashes and the associated problem areas and issues, the development of effective collision avoidance countermeasures can best be realized through a comprehensive knowledge and understanding of both the antecedent events which lead to crashes and the relative contributions of behavioral, vehicular, roadway, and environmental factors. In particular, the development of collision avoidance countermeasures involving the application of new and innovative technologies represents a promising avenue for using knowledge and understanding to significantly reduce the incidence of crashes.

The evolution of effective advanced technological countermeasures, however, goes hand-in-hand with the availability of a research tool to investigate the causes of crashes and the influence of vehicle design characteristics on the relationships among the driver, the vehicle, the roadway, and the environment. This is particularly important where advanced technology applications may themselves increase the potential for crashes or their severity under a given set of conditions.

The availability of this research tool is vital to fully understand and document the safety benefits and potential liabilities associated with a wide range of countermeasures and technological advancements, and to define the requirements associated with their design and implementation. Such a capability must allow for a flexible, comprehensive, and valid appraisal of countermeasures and advanced technology applications.

In this regard, recent technological innovations and developments in computers, computer graphics, computational speed and power, miniaturization, communications, and data acquisition and analysis have provided the opportunity to develop DASCAR, a system for addressing the wide range of issues associated with existing problem areas as well as those involving the development and implementation of new advanced technological systems within the motor vehicle-highway environment. These advances have also greatly enhanced the ability to develop the sophisticated tool needed to carry out a systematic and controlled evaluation of new technologies under operational or high fidelity conditions.

NHTSA envisions many future situations in which the effectiveness and consequences of new intelligent transportation systems (ITS) technologies will need to be studied in actual production vehicles. Such studies will enable evaluations in vehicles which are familiar to drivers. These studies would be further enhanced by the availability of a DASCAR that can be easily installed in these vehicles to enable specific vehicle configurations of interest (e.g., pedal placement, head-up displays) to be evaluated, thereby increasing the variety of vehicle options (incorporating advanced technology) that are available for study. Ideally, an approach is needed that would allow data collection from a variety of vehicle models and types, and would address the issue of driver familiarity.

Such an approach is embodied in the concept of a DASCAR that can be installed in a wide range of vehicles within a relatively short period of time. As a universally adaptable system, it provides researchers with the ability to record information on driver, vehicle, roadway, and environmental parameters. Furthermore, it enables the measurement of driver performance in the driver's own vehicle, thereby ensuring vehicle familiarity. It is also possible to measure driver performance in relation to any vehicle design characteristic at relatively little expense and effort, and makes it easy to update existing models of driver/vehicle behavior to reflect performance characteristics in vehicles of current manufacture. The availability of such information can lead to improved problem identification in crash avoidance research, as well as provide NHTSA with the capability to readily answer questions related to vehicle design characteristics not otherwise available. In addition, such a system has the potential to measure driver performance as it relates to the location of surrounding vehicles. This will allow the study of how drivers interact with other vehicles in their immediate vicinity.

3. REQUIREMENTS

The development effort for DASCAR was driven by a number of requirements which are briefly described below. They are discussed in more detail in Carter and Goodman (1994).

3.1 Parameters and measures

The data acquisition system is capable of collecting and analyzing driver-related, vehicular, and environment parameters and measures. Driver-related variables consist of driver control actions, equipment status, and physiological measures. Parameters and measures that are currently recorded by DASCAR are exhibited in Table 1. A few of the environment parameters are sensor derived; most of them are however video derived. The data acquisition system can collect other variables if a researcher so desires. All that would have to be done would be to add additional sensors.

3.2 Off-the-shelf and state-of-the-art

DASCAR consists of both off-the-shelf hardware and software, and state-of-the-art technology. ORNL procured most of the system required equipment. The hardware was subsequently modified as appropriate for DASCAR application. Some of the hardware and software had to be designed and developed from scratch.

Table 1. Variables Currently Collected by DASCAR

Driver Parameters	<i>Driver Control Actions</i>	Accelerator/throttle	Brake pedal
Steering wheel	Time between accelerator release and brake application (derived)	<i>Equipment Status</i>	Auxiliary device (e.g., side-object detection)
Brake lights	Hazard flasher	Headlights	Horn
Parking lights	Rear window defogger	Rear window wipers	Seat belt
Turn signals	Windshield wipers	<i>Physiological</i>	Core temperature
Electrocardiogram	Electroencephalogram	Electromyogram	Electrooculogram
Galvanic skin response	Gross body activity	Respiration	Skin temperature
Vehicle Parameters	Distance traveled (derived)	Elapsed time (derived)	Heading
Headway	Lateral acceleration	Lateral lane keeping	Longitudinal acceleration
Pitch	Roll	Tailway	Time-to-collision (derived)
Vehicle location	Velocity (derived)	Vertical acceleration	Yaw
Environment Parameters	<i>Sensor Derived</i>	Illumination	Lumination
Noise/sound	<i>Video Derived</i>	Car lights	Distracting lights, obstacles, and signs
Exits	Hand position	Haze/dust	Head movements
Intersections	One- or two-way traffic	Parked cars	Pedestrians
Posted speed limits	Precipitation	Road conditions	Road lighting
Road types	Surrounding field of view	Traffic conditions	Traffic events
Traffic lights	Turns/hills	Visibility/sight distance	Which lane you are in

3.3 Portability

The data acquisition system is portable. It can be installed on a particular vehicle quickly and can rapidly be removed and placed within another vehicle. It takes between one and two weeks to install the complete DASCAR within a new automobile or truck, depending on the vehicle type and configuration.

3.4 Automobiles and trucks

DASCAR was designed so that it can be positioned within virtually any passenger vehicle. It can be installed within a wide range of vehicle types (compact, intermediate, and large automobiles, vans, and small, mid-size, and large trucks) built by the three U.S. domestic vendors (General Motors, Ford, and Chrysler).

3.5 Unobtrusiveness and inconspicuousness

The data acquisition system is both unobtrusive to the driver and inconspicuous to the outside world. Placement of hardware within a vehicle does not obstruct the driver's primary task of driving. Instrumentation, cables, and wires connecting different

pieces of the system are hidden, well out of the view of the driver. Antennas, sensors, and cameras are situated on the exterior of the vehicle so that they cannot be seen by other drivers. As far as possible, the vehicle looks and drives like any other vehicle on the road.

3.6 Modularity and flexibility

DASCAR was modularly designed; that is to say, the system permits installation of only those data collection capabilities required for a particular study. An individual does not have to instrument the vehicle with the entire system in order to collect or record a subset of parameters. The data acquisition system was designed so that it has the flexibility to accommodate new data acquisition and sensor technologies as the state-of-the-art changes.

3.7 Three modes of data collection

DASCAR has three modes of data collection. The first consists of recording parameter data onboard the vehicle via a laptop computer. This mode provides a backup capability in the case of radio link failure or signal corruption during data transmission. The second mode comprises radio telemetry. The radio telemetry link is used to transmit data from the vehicle to a base station during use at a test track. The third includes cellular telephone equipment. This technology is employed to transmit data from a vehicle in an open road situation, anywhere in the U.S., to a base station that may be located a few, to many hundreds of miles away.

3.8 Extended periods of recording data and cost

DASCAR collects parameter data over two extremes of time - from as little as 20 minutes to as much as six months. The data acquisition system was designed with cost as a main consideration. Technical capabilities - cost tradeoff analyses were performed for each part of DASCAR.

4. SYSTEM OVERVIEW

DASCAR consists of five major elements: a data acquisition platform, a data storage and transmission system, a power supply, a sensor suite, and a video data system. A block diagram of the data acquisition system design is shown in Figure 1. The data acquisition platform contains both data acquisition boards and a computer system. It captures and processes signals from the various sensors installed within and around the vehicle. The data storage and transmission system is composed of several components: cellular telephone equipment, radio telemetry, a laptop computer, docking station, a small computer system interface (SCSI) hard drive, and a large removable SCSI hard drive. It receives, assembles, transmits, stores, and integrates the parameter data collected via the DASCAR sensor suite. The power supply includes three items, a battery, an isolator, and switching power supplies. These three elements were addressed in more detail in two earlier articles (Carter and Barickman, 1995; Carter, Spelt, and Barickman, 1996). The rest of this paper will concentrate on DASCAR's sensor suite and video data system.

5. SENSOR SUITE

5.1 Components and functions

The data acquisition system sensor suite comprises transducers, systems, devices, sensors, and meters to gather parameter data from the driver, vehicle, and environment. It includes: a linear position transducer, pedal force transducers, an accelerometer, an ambulatory data recording system (ADRS), a six degree-of-freedom (6 DOF) orientation sensor, a Hall effect sensor, an electronic compass, range sensors, radiometers/photometers, a sound level meter, a lateral position lane tracking system, and a global positioning system (GPS) receiver. A drawing of the sensor suite and the major hardware components, along with their relative placement within a vehicle, is displayed in Figure 2.

The linear position transducer is employed to collect accelerator/throttle and steering wheel data from the vehicle. The pedal force transducers are utilized to record brake pedal application force. The accelerometer is used to collect gross body activity data from the vehicle driver. The ADRS is employed to collect core temperature, electrocardiogram, electroencephalogram, electromyogram, electrooculogram, galvanic skin response, respiration, and skin temperature data from the driver.

Figure 1. Block diagram of the data acquisition system

Figure 2. Major hardware components and sensor suite shown in their relative placement within the vehicle

Major Hardware Components

1. Data Acquisition Platform
2. DC-DC Power Supply (15V;12V;5V)
3. 12V Battery System
4. 486DX2-66MHz Lap-Top Computer
5. Radio Telemetry Tx
6. Satellite Uplink Tx
7. Video Digitizer & Compression System

Sensor Suite

8. Six-Degree of Freedom Sensor
9. Lane Tracking Unit
10. Headway / Tailway Measuring Device
11. Micro CCD Video Camera {3}
12. VITC; SVHS; Quad Picture Processor
13. Electronic Compass
14. Linear Position Transducers (string pots)
15. Pedal Force Transducer (load cell)
16. Accelerometer
17. Hall Effect Sensor
18. Meteorological Sensor
19. Sound Level Meter
20. Photometer

• Various activation switches, contacts, & sensors for physiological monitoring are located throughout the vehicle.

The 6 DOF orientation sensor is utilized to record acceleration (lateral, longitudinal, and vertical), pitch, roll, and yaw data from the vehicle. The Hall effect sensor is used to collect distance traveled and velocity data from the vehicle. The electronic compass is employed to record heading data from the vehicle. The range sensors are utilized to collect headway and tailway data from the vehicle. The lateral position lane tracking system is used to record lateral lane keeping data from the vehicle. The GPS receiver is employed to collect vehicle location and route traveled.

The radiometers/photometers are utilized to record ambient illumination and lumination data from the environment outside the vehicle. The sound level meter is used to collect sound and both steady state and impulse noise as heard by the driver inside the vehicle.

5.2 Specifications

5.2.1 Driver parameters

Specifications for the sensors which gather driver-related parameters are shown in Tables 2 through 4. Table 2 presents specifications for the DASCAR driver control actions. It provides the range for each parameter. Table 3 lists the specifications for the sensors employed for recording equipment status. It furnishes information how each sensor is measured. Table 4 exhibits the specifications for the data acquisition system physiological measures data collection. It supplies material on the fixed rate, analog-to-digital (A/D) resolution, and range for each parameter-sensor combination.

Table 2. Driver Control Actions

Parameter	Sensor	Range
Accelerator/throttle	Linear position transducer	dc to full scale
Brake pedal	Pedal force transducer	0.4 to 136.0 kilograms
Steering wheel	Linear position transducer	dc to full scale

Table 3. Equipment Status

Parameter	How Measured
Auxiliary device	on/off
Brake lights	on/off
Hazard flasher	on/off
Headlights	on/off
Horn	on/off
Parking lights	on/off
Rear window defogger	on/off
Rear window wipers	on/off
Seat belt	on/off
Turn signals	on/off
Windshield wipers	on/off

Table 4. Physiological Measures

Parameter	Sensor	Fixed Rate	A/D Resolution	Range
Core temperature	ADRS	1 hertz	12 bit	0 - 500 degrees K
Electrocardiogram	ADRS	50 hertz	8 bit	1 to 25 hertz
Electroencephalogram	ADRS	50 hertz	8 bit	1 to 25 hertz
Electromyogram	ADRS	10 hertz	8 bit	20 to 500 hertz
Electrooculogram	ADRS	10 hertz	8 bit	0.08 to 5.0 hertz
Galvanic skin response	ADRS	10 hertz	12 bit	0 to 5 volts
Gross body activity	Accelerometer	to be determined	16 bit	to be determined
Respiration	ADRS	10 hertz	8 bit	not applicable
Skin temperature	ADRS	1 hertz	12 bit	0 - 500 degrees K

5.2.2 Vehicle parameters

Specifications for the sensors which gather the vehicle-related parameters are shown in Table 5. It provides full scale information.

Table 5. Vehicle Parameters

Parameter	Sensor	Full Scale
Heading	Electronic compass	0 to 359.9 degrees
Headway	Range sensor	0 to 100 meters
Lateral acceleration	6 DOF orientation sensor	-2 to +2 gravity
Lateral lane keeping	Lateral position lane tracking system	0 to 1.8 meters
Longitudinal acceleration	6 DOF orientation sensor	-2 to +2 gravity
Pitch	6 DOF orientation sensor	+/- 100 degrees per second
Roll	6 DOF orientation sensor	+/- 100 degrees per second
Tailway	Range sensor	0 to 50 meters
Time-to-collision	Range sensor	0.1 to 4.0 seconds
Vehicle location	GPS receiver	not applicable
Velocity	Hall effect sensor	0 to 200 kilometers per hour
Vertical acceleration	6 DOF orientation sensor	-2 to +2 gravity
Yaw	6 DOF orientation sensor	+/- 200 degrees per second

5.2.3 Environment parameters

Specifications for the sensors which record environment parameters are exhibited in Table 6. The table shows material on full scale.

Table 6. Environmental Parameters

Parameter	Sensor	Full Scale
Illumination	Radiometer/photometer	not applicable
Lumination	Radiometer/photometer	not applicable
Noise/sound	Sound level meter	30 - 140 decibels

6. VIDEO DATA SYSTEM

The DASCAR video data system comprises both color and black-and-white video micro cameras, a vertical interval time code (VITC) generator, a digital quad picture processor, a compressed video digital storage and retrieval system (CVDSRS), a digital picture transmission system, and a super-VHS recorder. The video data system is graphically depicted in Figure 3.

The video micro cameras are employed to record video data inside the vehicle and in the outside environment. They consist of camera heads, lenses, control units, and cables. The VITC generator is utilized to time code the video output from the micro cameras and to provide video data synchronization with the sensor data. The digital quad picture processor is used to display, tape record, and transmit images from four video micro cameras at one time. Both the CVDSRS and super-VHS recorder are employed to collect and handle video from the video micro cameras installed within and around the vehicle. The CVDSRS digitizes and compresses analog video material in real time. The digital picture transmission system is utilized to send high quality color pictures to the central data collection/analysis facility in near real time. (Compressed digitized video has too large a bandwidth to transmit full motion video from a moving vehicle with current communications technologies.)

7. CENTRAL DATA COLLECTION/ANALYSIS FACILITY

A central data collection/analysis facility was also assembled to manage all of the DASCAR sensor and video data. The facility is based around a personal computer platform. Support systems include: a moving picture experts group decoder digital video system, a digital quad picture processor, a super-VHS recorder, a super-VHS monitor, and a digital picture receiver system.

Collection of the DASCAR sensor data at the central data collection/analysis facility is handled in several ways: it is transferred via removable SCSI hard disk; it is received through radio telemetry equipment; and/or it is received through cellular/land lines. Video data is transferred via analog tape(s) or SCSI hard drive. The digital picture receiver system is used to receive still video images from the field.

8. USES OF DASCAR

DASCAR will function as the cornerstone research platform for NHTSA during the next decade, and nearly all of NHTSA's crash avoidance research will be conducted utilizing copies of the data acquisition system. DASCAR will be employed to collect normative driver performance data, support system performance guideline development, evaluate both conventional and ITS technologies, support simulator validation, and fine tune simulators (e.g., scenarios, motion algorithms, and driver feedback). Normative driver performance data include both long-term naturalistic and traffic incident/near miss data. DASCAR will allow normative driver data to be collected within and between subjects, between various vehicle types (varying in size, weight, and vehicle design features), and under a wide variety of roadway and environmental conditions (such as visibility and roadway conditions). The data acquisition system will support system performance guideline development for vision enhancements, the condition of the driver, and for a variety of crash scenarios (lane change, merging, backing, rear-end,

Video Data System

Micro CCD Cameras and Digital Signal Processors

Figure 3. Graphical depiction of the DASCAR video data system

intersection, and roadway departure collisions). Examples of conventional technologies to be evaluated via DASCAR include lighting, mirrors, dashboard configuration, and control configuration. ITS technologies consist of crash avoidance systems (e.g., intelligent cruise control), driver navigation and traveler information systems, and other advanced in-vehicle systems (e.g., active suspension and anti-lock brake systems).

9. ACKNOWLEDGMENT

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